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Air leaks following pulmonary resection for malignancy: risk factors, qualitative and quantitative analysis☆

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Institutional Report

Abstract

Air leaks are a common complication of pulmonary resection. The aims of this study were to analyze risk factors for postoperative air leak and to evaluate the role of air leak measurement in identifying patients at increased risk for cardiorespiratory morbidity and prolonged air leak. From March to December 2009, 142 consecutive patients underwent pulmonary resection for malignancy and were prospectively followed up. Preoperative and intraoperative risk factors for air leak were evaluated. Air leaks were qualitatively and quantitatively labeled twice daily. There were 52 (36.6%) patients who had an air leak on day 1, and 32 (22.5%) who had an air leak on day 2. Air leak was ≥180 ml/min in 12 (37.5%) of these patients. Independent predictors of air leak on day 2 included type of pulmonary resection, presence of adhesions, and incomplete fissures. Cardiorespiratory morbidity was significantly higher (34.4%) in patients who experienced air leak on day 2 than in those who did not (10.9%) (P=0.002). Nine (75%) out of 12 patients with air leak ≥180 ml/min on day 2 had prolonged air leak (greater than five days) (P=0.0001).

Keywords: Lung cancer; Postoperative complications; Air leak

1. Introduction

A number of techniques have been developed to prevent alveolar air leaks following pulmonary resection [1, 2]. However, postoperative air leaks are still a frequent complication of thoracic surgery. Air leaks lasting beyond postoperative day (POD) 5 can cause increased infectious or cardiorespiratory morbidity, require additional management, prolong hospital stay, and increase costs [3]. In the literature, there is a paucity of objective data on air leak characterization following pulmonary resection, and high variability in the management of this complication [4–7]. The aims of this study were to analyze risk factors for postoperative air leak and to evaluate the role of air leak measurement in identifying patients at increased risk for major cardiorespiratory morbidity and prolonged air leak.

2. Materials and methods

This single-institution retrospective study includes 142 consecutive patients undergoing elective pulmonary resection for primary or secondary lung malignancy from March to December 2009. Patients undergoing video-assisted thoracoscopic pulmonary resection or pneumonectomy were excluded.

Preoperative evaluation consisted in a complete history and physical examination, laboratory tests, pulmonary function tests, blood gases, contrast-enhanced chest and upper abdomen computed tomography (CT) scanning, and integrated positron emission tomography and CT-scan. Additional tests, including bronchoscopy and a brain CT-scan, were performed as appropriate.

As a general rule, anatomical lung resections with systematic lymph node dissection were performed for primary bronchogenic carcinoma, while wedge resection with lymph node sampling was used in patients undergoing metastasectomy. Pleural adhesions were managed with electrocautery, and incomplete fissures were stapled. After completion of lung resection, air leaks were identified by rinsing the inflated lung with water. Air leaks classified as grade 3 (coalescent bubbles) [8] were sutured, those of grade 2 (stream of bubbles) were either sutured or treated with fibrin glue or a collagen patch, and grade 1 lesions (single bubbles) were left untreated. Two 24-Fr chest tubes were used after bilobectomy or lobectomy, and only one after segmentectomy or wedge resection. Chest tubes were connected to the drainage system at –20 cmH_2O of suction until POD 2, when, if minimal or no air leak was present, one chest tube was removed and the other converted to water seal. Otherwise, the remaining tube was placed at

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Fig. 1. The volumetric air leak meter contained within the chest drainage system that was used in the study. Air leaks are qualitatively assessed in the 'bubbling mode' and quantitatively graded in the 'volumetric mode' using the volume of water contained in the water-seal chamber (45 ml) as a unit of measure.

-10 cmH_2O of suction. In the absence of air leak and high-output fluid drainage (>250 ml/day), the last tube was removed on POD 4. In patients with prolonged air leaks, defined as ongoing air leaks after POD 5 [3], chest tubes were changed to water seal on POD 7 unless increasing subcutaneous emphysema and/or symptomatic pneumothorax developed.

Operative mortality included patients who died within 30 days after operation. Major cardiorespiratory morbidity included hemodynamically unstable arrhythmia, adult respiratory distress syndrome (ARDS), respiratory failure, pneumonia, poor clearance of pulmonary secretions with or without atelectasis necessitating bronchoscopy and/or non-invasive assisted ventilation, and pleural empyema.

Air leaks were assessed twice daily. Qualitative and quantitative assessments of air leaks were performed by using a chest drainage system (Rome; Eurosets, Medolla, Italy), which incorporates a volumetric air leak meter. Air leaks were qualitatively labeled as forced expiratory only, expiratory, and continuous [4], while the air leak detector housed in the drainage system (Fig. 1) allowed quantitative scoring of the air leaks in milliliters per minute (ml/min).

Continuous data are reported with medians and ranges. Categorical data are presented as counts and percentages. Variables tested in order to identify predictors of postoperative air leaks included patient characteristics (demographic information, significant comorbidity, pulmonary function parameters, blood gases, and preoperative chemotherapy) and operative factors [diagnosis, site of disease, type of pulmonary resection, presence of pleural adhesions defined as adhesions occupying at least 30% of a lung [5], status of fissures, presence of macroscopic emphysematous changes in the remaining lobe(s), and presence and magnitude of air leaks at the end of the operation]. These variables were evaluated as categorical and compared at univariate analysis by means of the χ^2, Fisher's exact, and Kruskal-Wallis tests, as appropriate. Predictors of postoperative air leaks with $P<0.10$ at univariate analysis were tested for their independent role at multivariate analysis. A P-value of <0.05 was considered statistically significant. The SPSS statistical software (SPSS Inc, Chicago, IL, USA) was used.

3. Results

The study population included 142 consecutive patients undergoing elective pulmonary resection for lung malignancy. Most patients (108/115; 93.9%) operated on for primary bronchogenic carcinoma underwent anatomical lung resection (five bilobectomy, 101 lobectomy, and two segmentectomy) with systematic lymph node dissection. In 21 out of 27 (77.7%) patients undergoing metastasectomy, wedge resection and lymph node sampling were performed. In the remaining six patients with lung metastases, two lobectomies and four segmentectomies were performed. Patient characteristics are summarized in Table 1.

Following surgery, 40 (28.2%) out of 142 patients developed 58 postoperative complications. Major cardiorespiratory morbidity occurred in 23 patients (16.2%) and included hemodynamically unstable arrhythmia ($n=4$), ARDS ($n=1$), respiratory failure ($n=4$), pneumonia ($n=2$), poor clearance of pulmonary secretions with ($n=8$) or without ($n=7$) atelectasis, and pleural empyema ($n=1$). Other complications were prolonged air leak ($n=13$), intra- and/or postoperative bleeding requiring transfusion(s) ($n=9$), transient atrial fibrillation ($n=7$), acute renal failure ($n=1$), and superficial wound infection ($n=1$). Three patients (2.1%) died within 30 days of surgery [respiratory failure ($n=2$), and ARDS ($n=1$)].

Fifty-two patients (36.6%) on POD 1 and 32 patients (22.5%) on POD 2 had an air leak (10 forced expiratory only, 21 expiratory, and one continuous). The 10 patients with forced expiratory air leak had their chest tubes converted to water seal. The remaining 22 patients had their chest tubes placed at -10 cmH_2O suction: seven of them developed symptomatic pneumothorax and/or subcutaneous emphysema and were placed back on -20 cmH_2O suction. On the morning of POD 5, 13 patients (9.1%) showed a persistent air leak: seven patients with forced expiratory only air leaks had their chest tubes placed on water seal since POD 7, while five patients with persistent expiratory air leaks remained on -10 cmH_2O suction. Eventually, in these 12 patients, air leaks stopped within a median of 5.5 additional days (range 3–11 days) after POD 5. One patient with persistent continuous air leak received a Heimlich valve and was discharged home on POD 18. On POD 25, the patient was readmitted to the hospital because of an empyema and was treated with dependent drainage.

Risk factors for air leak on POD 2 are shown in Table 1. At multivariate analysis, type of pulmonary resection ($P=0.01$), presence of pleural adhesions ($P=0.04$), and incomplete fissures ($P=0.026$) emerged as independent predictors of air leak.

Table 1. Characteristics of the study population (n=142) and according to presence of air leak on postoperative day 2 (POD 2) (n=32)

Characteristic	Overall		Air leak POD 2		*P*-value
	No.	%	No.	%	
Age, years, median (range)	66.8 (15–84)				0.5
<70	87	61.3	18	20.7	
≥70	55	38.7	14	25.5	
Sex					0.18
Male	100	70.4	26	26	
Female	42	29.6	6	14.3	
Cardiovascular disease[a]					0.03
Yes	18	12.7	8	44.4	
No	124	87.3	24	19.4	
Insulin-dependent diabetes					0.19
Yes	7	4.9	3	42.9	
No	135	95.1	29	21.5	
FEV_1% pred., median (range)	99 (52–156)				0.004
<80	28	19.7	12	42.9	
≥80	114	80.3	20	17.5	
FEV_1/FVC% pred., median (range)[b]	92 (53–155)				0.02
<70	6	4.4	4	66.7	
≥70	129	95.6	25	19.4	
RV% pred., median (range)[c]	108 (54–213)				0.02
<120	98	69.5	17	17.3	
≥120	43	30.5	15	34.9	
DLCO% pred., median (range)	79 (36–135)				0.6
<80	71	50	15	21.1	
≥80	71	50	17	23.9	
PaO_2, mmHg, median (range)[d]	83 (60–114)				0.3
<70	9	6.4	1	11.1	
≥70	131	93.6	31	23.7	
$PaCO_2$, mmHg, median (range)[d]	38 (29–47)				0.3
<45	135	96.4	30	22.2	
≥45	5	3.6	2	40	
Preoperative chemotherapy					1.0
Yes	11	7.7	2	18.2	
No	131	92.3	30	22.9	
Lung malignancy					0.009
Primary	115	81	31	27	
Secondary	27	19	1	3.7	
Site of disease					0.5
Right	89	62.7	22	24.7	
Left	53	37.3	10	18.9	
Type of pulmonary resection					0.005
Bilobectomy	5	3.5	3	60	
Lobectomy	103	72.6	28	27.2	
Segmentectomy	6	4.2	0	0	
Wedge resection	28	19.7	1	3.6	
Pleural adhesions					0.006
Yes	55	38.7	19	34.5	
No	87	61.3	13	14.9	
Status of fissures					0.001
Complete	53	37.3	4	7.5	
Incomplete	89	62.7	28	31.5	
Macroscopic emphysematous changes					0.16
Yes	13	9.1	5	38.5	
No	129	90.9	27	20.9	
Air leaks at the end of operation[e]					0.06
0	92	64.8	18	19.6	
1	29	20.4	6	20.7	
2	15	10.6	4	26.7	
3	6	4.2	4	66.7	

[a]Includes history of myocardial infarction, cerebrovascular accident, cardiac surgery, coronary or peripheral angioplasty and stenting, abdominal aortic aneurysm surgery, and compensated or prior heart failure. [b]Seven patients with missing data are excluded. [c]One patient with missing data is excluded. [d]Two patients with missing data are excluded. [e]Air leaks at the end of operation were classified according to the criteria outlined by Macchiarini et al. [8]. DLCO, lung diffusion capacity for carbon monoxide; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; RV, residual volume. Values are expressed as a percentage of predicted (pred.) value for age, gender and height [5].

The occurrence of air leak on POD 2 led to a significantly increased risk of major cardiorespiratory morbidity (P=0.002): 11 (34.4%) out of 32 patients with an air leak on POD 2 developed major cardiorespiratory complications. Moreover, the magnitude of air leak on POD 2 was predictive of prolonged air leak: a significantly greater proportion of patients with an air leak ≥180 ml/min on POD 2 (9/12; 75%) experienced prolonged air leak than did patients with an air leak <180 ml/min on POD 2 (4/130; 3.1%) (P=0.0001).

Finally, median hospital stay for patients without air leak on POD 2 was seven days (range 4–18; mean 7.8±3 days) while for patients with air leak on POD 2 it was 11 days (range 6–21; mean 11.1±4.2 days) (P=0.0001).

4. Discussion

As a consequence of refinements in surgical technique and the development of new technology [1, 2], the incidence of postoperative air leaks after pulmonary resection has decreased over time. Even so, postoperative air leaks continue to be a challenging complication of thoracic surgery. Out of 142 consecutive patients undergoing pulmonary resection for malignancy, 52 patients (36.6%) had an air leak on POD 1, 32 (22.5%) on POD 2, and 13 (9.1%) developed a prolonged air leak lasting beyond POD 5. These results are similar to those appearing in the literature, taking into account that the range of reported postoperative air leak and prolonged air leak rates may reflect varying criteria of patient selection, differences in type of pulmonary resection, and different prolonged air leak definitions [6, 7, 9, 10].

Several factors have been implicated in the occurrence of postoperative air leaks. Identified independent predictors of postoperative air leaks include both preoperative factors (patient's gender, history of steroid use, pulmonary function tests consistent with chronic obstructive pulmonary disease) [9, 11, 12] and intraoperative factors (type of pulmonary resection and presence of pleural adhesions) [9, 12]. In our series, independent risk factors for postoperative air leak on POD 2 were type of pulmonary resection, presence of pleural adhesions, and incomplete fissures. However, by using reliability statistics [6], only type of anatomical lobe resected, date of operation, and surgeon emerged as independent predictors of air leak, while propensity score analysis matching cases with controls showed no predictive variables for prolonged air leak at logistic regression [7].

In this study, postoperative air leaks lasting at least two days after pulmonary resection were found to be associated significantly with major cardiorespiratory complications. Conflicting information exists regarding the association of air leaks with postoperative morbidity. Brunelli et al. [12] found that patients with air leaks lasting longer than seven days experienced an increased rate of postoperative complications; however, this association could be explained by the effect of common risk factors, such as impaired lung function. Subsequently, Brunelli et al. [10] described a significantly higher rate of empyema in patients with air leaks longer than seven days but no difference in the rate of other cardiorespiratory complications compared with patients without prolonged air leaks. On the other hand, Okereke et al. [6] showed that any air leak, irrespective of duration, is independently associated with postoperative cardiac and respiratory complications. These discrepancies may well reflect varying criteria of patient selection and data definition.

Complications, inadequate pain control, and non-medical factors are the primary causes that determine length of hospital stay for patients undergoing pulmonary resection [11, 13]. The most common complications that prolong hospital stay are major cardiorespiratory morbidity and postoperative air leaks. Our series is no exception: median hospital stay was seven days in patients without air leak on POD 2 compared with 11 days in patients with air leak on POD 2 (P=0.0001). Air leaks eventually stopped within a median of 5.5 days (range 3–11 days) in 12 out of 13 patients with an air leak lasting beyond POD 5. One patient with prolonged air leak was discharged home on POD 18 with a Heimlich valve. Indeed, having patients confined to the hospital until air leak cessation permits more accurate definition of air leak duration and timely chest tube removal [1]. On the other hand, outpatient management of prolonged air leak with a suctionless device requires patients to be educated on the management of the drainage system and is fraught with a small risk of expanding pneumothorax and empyema. Interestingly, Cerfolio et al. [14] reported a series of 194 patients who had an air leak on POD 4 and were sent home with their tube attached to an outpatient suctionless device. These patients had their chest tubes in situ for a median of 16.5 additional days after discharge.

The volumetric air leak meter contained within the chest drainage system used in this study allowed both qualitative and quantitative air leak assessments. The quantitative measurement of air leaks showed prognostic value: patients whose air leaks did not stop by POD 3 had significantly higher air leaks on POD 2 than patients whose air leaks did (median 180 ml/min vs. 45 ml/min; P=0.005). Furthermore, patients with air leaks ≥180 ml/min on POD 2 were at increased risk of prolonged air leaks compared with patients with air leaks <180 ml/min on POD 2 (75% vs. 3.1%; P=0.0001). In these patients, an early pleurodesis could be considered to seal the leak [7].

This single-institution study has several limitations. First, the retrospective design could have introduced biased information. Second, the small sample size and the absence of a propensity score analysis limit the power of our statistical analysis.

In conclusion, postoperative air leaks remain a common, challenging complication of elective pulmonary resection for lung malignancy. Predictive factors of air leaks on POD 2 are type of pulmonary resection, presence of pleural adhesions, and incomplete fissures. The occurrence of air leaks on POD 2 is associated with a significant increase in major cardiorespiratory morbidity and length of hospital stay. The magnitude of air leaks on POD 2 is a statistically significant predictor of prolonged air leak (longer than five days).

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